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(21) International Application Number: PCT/GB99/01589 (22) International Filing Date: 19 May 1999 (19.05.99) (30) Priority Data: 9810686.7 19 May 1998 (19.05.98) GB (71) Applicant (for all designated States except US): KINGS COLLEGE LONDON [GB/GB]; Strand, London WC2R 2LS (GB). (72) Inventors; and (75) Inventors/Applicants (for US only): WU, Jianjun [CN/GB]; 32 Marney Road, Reading RG6 3AB (GB). AGHVAMI, Abdol, Hamid [GB/GB]; 54 Mountfield Road, London W5 2NQ (GB). (74) Agent: COHEN, Alan, Nicol; 2 Grove Place, Tatsfield, Westerham, Kent TN16 2BB (GB).		(81) Designated States: AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, CA, CH, CN, CU, CZ, DE, DK, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MD, MG, MK, MN, MW, MX, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, UA, UG, US, UZ, VN, YU, ZW, ARIPO patent (GH, GM, KE, LS, MW, SD, SL, SZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GW, ML, MR, NE, SN, TD, TG). Published With international search report.	
(54) Title: DUAL DIRECTION CHANNEL ESTIMATOR <pre> graph LR A[Midamble and first half data] --> B[Channel Estimator] B --> C[CIR for Viterbi Equaliser] D[Midamble] --> E[Cross-correlator] E <--> B E <--> F[Channel Estimator] G[Midamble and second half data] --> F F --> H[CIR for Viterbi Equaliser] </pre>			
(57) Abstract In the Global System for Mobil Communication (GSM) an improvement in estimating the channel impulse response (CIR) is obtained by starting up two channel estimators using the midamble and obtaining channel estimations with split burst, the two estimations are then cross-correlated to obtain the estimated CIR.			

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DUAL DIRECTION CHANNEL ESTIMATOR

The present invention relates to a method for improving the working of mobile telephone communications particularly in the Global System for Mobile Communication (GSM).

GSM is a digital system which will give a higher quality of service than analogue systems and has a higher capacity for users than in an analogue system.

In GSM the communication has a burst structure and it is necessary to estimate the channel impulse response (CIR). There is a problem in estimating the CIR in the current GSM system. In the current GSM equaliser, the overall channel impulse response (CIR) is estimated by cross-correlating the received signals in the midamble portion with the known midamble sequence. Based on the assumption of a static channel during the time slot, the estimated CIR taps are used throughout the entire burst. It has found that the performance of the current channel estimation techniques suffers at least 2 dB degradation when compared with the benchmark, defined as the performance when ideal CIR taps are available at the equaliser.

The degradation can easily be seen with the following example. If a car is travelling at 120 kilometres per hour, its Doppler frequency shift will be about 100 Hz at the current radio frequency. The period of the Doppler frequency is 10ms. On the other hand, the GSM burst is about 0.577ms, thus it takes about one-eighth the half Doppler frequency period. Future personal land mobile telecommunication systems (IMT-2000)/UMTS) will use 2GHz, so the Doppler frequency shift will be 220Hz at 120 kilometres per hour. This means that during the burst the fading could vary from nearly maximum to minimum. Therefore, the assumption of a (quasi) channel is not true and tracking the CIR estimation during the data mode will be compulsory.

We have devised a system for reducing or overcoming this problem

According to the invention there is provided a method for estimating the CIR in GSM a system in which method two channel estimators are started up using the midamble and channel estimations are obtained by channel estimators using the midamble with split burst, the two estimations are then cross-correlated to obtain the estimated CIR.

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In an alternative embodiment of the invention an unbiased estimation method can be used in place of a cross-correlator to obtain the CIR.

- 5 The current channel estimation method can be used to fast start-up the two channel estimators and RLS algorithms can be used to track the changes of the channel and update the CIR during the data mode.

A block diagram of the method of the present invention is shown in Fig. 1.

- 10 In carrying out the method of the present invention preferably firstly the midamble is used to start-up both channel estimators and secondly channel estimations are obtained by channel estimators using midamble with split burst.

- 15 By using split burst, full advantage can be taken of the cross-correlator and this reduces the delay introduced by the channel estimators. The re-use of midamble in both channels can reduce or overcome the inaccuracy from the cross-correlator under Gaussian noise and co-channel interference.

- 20 To maximise the transmission rate of useful data over the burst, preferably an estimate of the sampled CIR is needed in the shortest time, with the shorter the time the better the transmission rate, preferably therefore an optimum estimation process is used together with training signal to enable a best estimate of the CIR to be obtained.

- 25 When an unbiased estimation method is used instead of cross-correlation method the description of the algorithm of the unbiased channel estimator is given by:

$$R_i = H_k S + N_i \quad (2)$$

$$R_i S^{-1} = H_k + N_i S^{-1} \quad (3)$$

30 $E[N_i S^{-1}] = 0 \quad (4)$

Thus

$$H_k = R_i S^{-1} \quad (5)$$

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where H_k is an m-component row vector which represents the CIR, H_k is an m-component row vector which represents the optimum estimate of CIR, S is an m by m element matrix of transmitted signals and R_i is an m-component row vector of received signals. N_i is an m-component row vector of additive white Gaussian noise.

5

If we can get the inverse matrix of S , an unbiased linear estimate of H_k will be obtained. Because $H_k S = R_i$, the estimated H_k maximises its likelihood function $P(R_i / H_k)$ and minimises $E|H_k S - R_i|^2$. Thus H_k is also the maximum likelihood estimate of H_k from R_i .

10

This method will use fewer bits than the cross-correlation method for the same CIR length. The extra bits in the midamble can be used for further channel estimation. Better channel estimation can be expected by averaging these two estimations. This method only needs to choose another sequence in midamble and requires no further modification in GSM system.

15

An embodiment of the proposed channel estimator of the present invention is described as follows:

20 For the proposed channel estimator the cross-correlation estimation or unbiased channel estimation is used to fast start-up the transversal filter channel estimator which is used during the data mode in the channel estimator. The midamble will go through the channel estimator again to train the channel estimator. This double use of the midamble guarantees the convergence of the channel estimator. This method is an optimum estimation process and solves the convergence speed problem of channel
25 estimators. Dual direction channel estimation can reduce the process delay to half and reusing the midamble will take full advantage of the known sequence.

30

This is illustrated in Fig. 2.

Use of Transversal Filter Channel Estimator

During data mode, there could be some errors in the decisions, therefore use of an unbiased estimation or cross-correlating method could give rise to difficulties. To
35 overcome this a transversal filter channel estimator can be used during the data mode

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in the proposed channel estimator and the structure of the LMS channel estimator is shown in Figure 3.

- 5 For the proposed channel estimator, tentative soft decisions can be used in order to use more reliable decisions $S(k) = \{S_{k-n}, S_{k-n+1}, \dots, S_{k-1}, S_k\}^T$

So $S(k)$ now is not only time dependent but also tentative soft decision dependent because of the channel estimate. The channel parameters h_j can be estimated by using the LMS or Kalman algorithm.

10

The channel estimator may introduce some delays depending on the structure, therefore the estimate of CIR is a delayed estimate and a predicted CIR is needed. The longer the delay before using a soft decision, the more reliable that decision is for the channel estimator. However, if decisions with longer delays are used, prediction
15 with more than one step will be required.

The least-square fading memory prediction can be used for fast changing channels. The equations are given by

20
$$E_i = H_i - H_{i,i-1} \quad (6)$$

$$H'_{i-1,i} = H'_{i,i-1} + (1-\theta)^2 E_i \quad (7)$$

$$H_{i-1,i} = H_{i,i-1} + H'_{i-1,i} + (1-\theta^2) E_i \quad (8)$$

25

$$H_{i-2,i} = H_{i,i-1} + H'_{i-1,i} \quad (9)$$

- where H'_{i-1} means one step prediction of the first derivative H'_{i-1} , and θ is a real-valued constant in the range 0 to 1. The bigger the value of θ , the greater the number
30 of estimates that are effectively involved in a prediction.

The method of the invention enables better channel estimation can be obtained and the degradation in current systems can be overcome.

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Claims

1. A method for estimating the CIR in GSM a system in which method two channel
5 estimators are started up using the midamble and channel estimations are obtained by
channel estimators using the midamble with split burst, the two estimations are then
processed to obtain the estimated CIR.
2. A method as claimed in claim1 in which the two estimations are cross-correlated
10 to obtain the estimated CIR.
3. A method as claimed in claim1 in which the two estimations are processed by
means of an unbiased estimation method to obtain the estimated CIR.
- 15 4. A method as claimed in claim 1, 2 or 3 in which a channel estimation method is
used to fast start-up the two channel estimators.
5. A method as claimed in claim 4 in which RLS algorithms are used to track the
changes of the channel and update the CIR during the data mode.
20
6. A method as claimed in any one of the preceding claims in which firstly the
midamble is used to start-up both channel estimators and secondly channel
estimations are obtained by channel estimators using midamble with split burst.
- 25 7. A method as claimed in any one of the preceding claims in which an optimum
estimation process is used together with a training signal to enable a best estimate of
the CIR to be obtained.
8. A method as claimed in any one of the preceding claims in which the cross-
30 correlation estimation or unbiased channel estimation is used to fast start-up the
transversal filter channel estimator which is used during the data mode in the channel
estimator the midamble going through the channel estimator again to train the
channel estimator.

35

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9. A method as claimed in any one of the preceding claims in which a transversal filter channel estimator is used during the data mode in the channel estimator.

5

10. A method as claimed in any one of the preceding claims in which the least-square fading memory prediction is used for fast changing channels.

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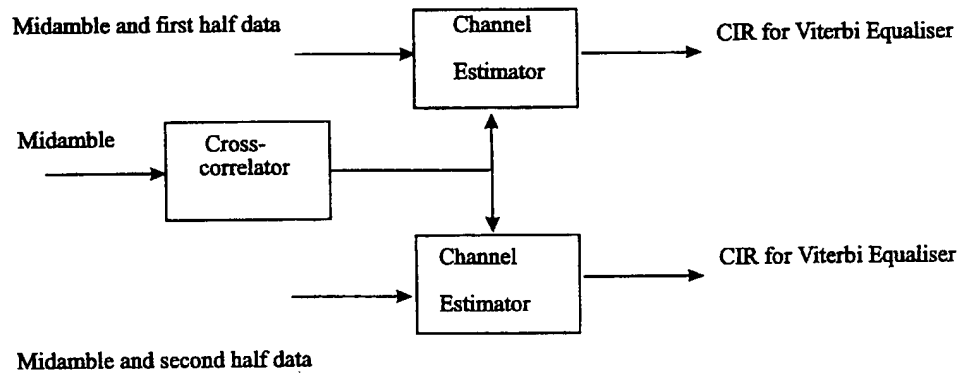


Fig. 1

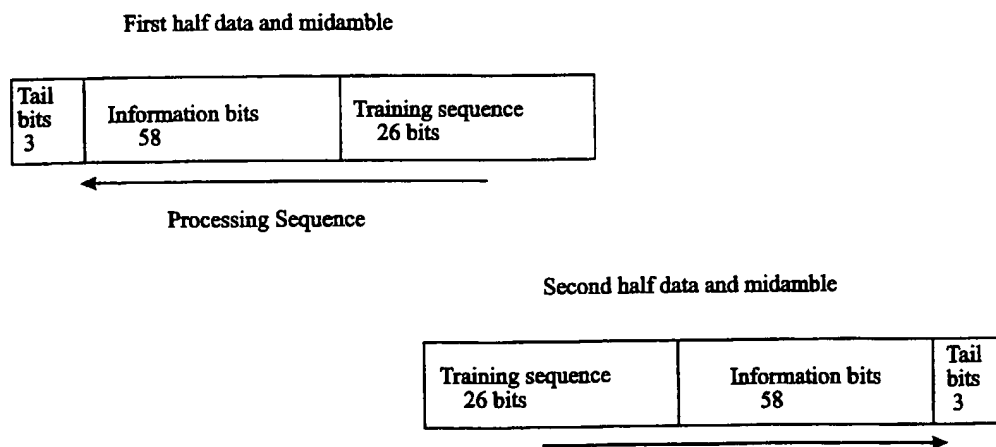


Fig. 2

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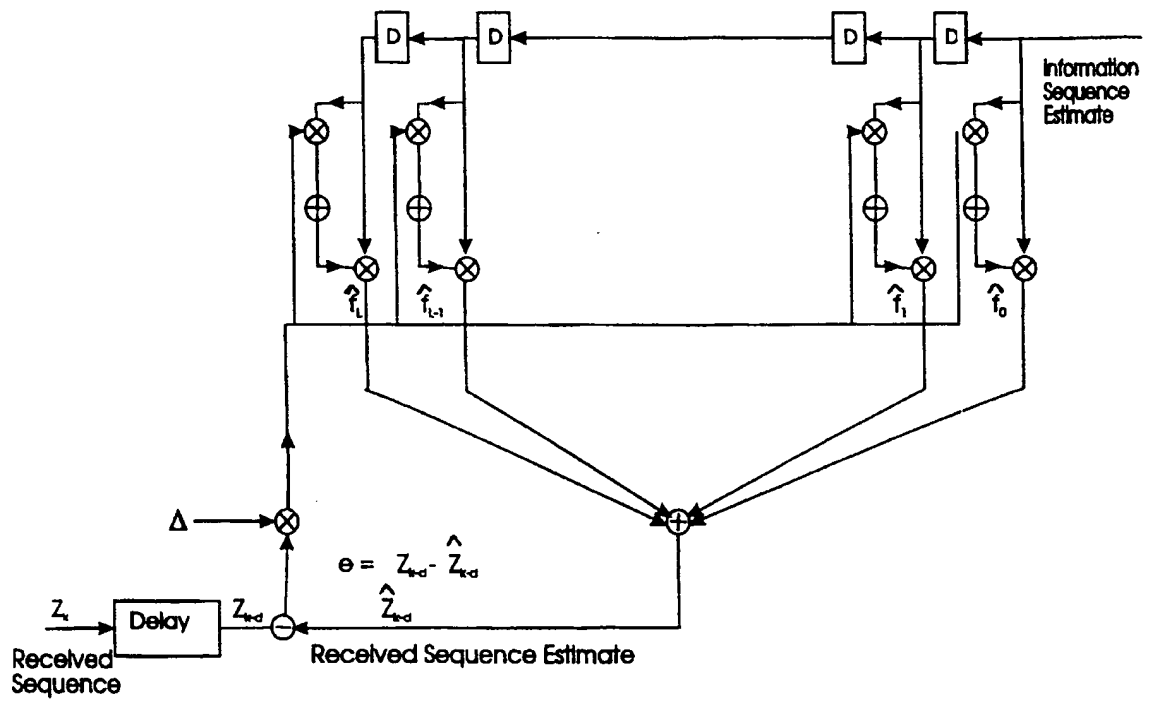


Fig. 3

INTERNATIONAL SEARCH REPORT

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A. CLASSIFICATION OF SUBJECT MATTER
IPC 6 H04L25/02 H04B7/005

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC 6 H04L H04B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	EP 0 520 969 A (HUGHES AIRCRAFT CO) 30 December 1992 (1992-12-30)	1
Y	abstract; figures 1-3 page 2, line 30 - line 58 page 3, line 52 - page 4, line 4 page 4, line 43 - page 5, line 7 claims 2,3 --- -/--	2-10

☒ Further documents are listed in the continuation of box C.

☒ Patent family members are listed in annex.

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Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	<p>WU J ET AL: "A NEW ADAPTIVE EQUALIZER WITH A CHANNEL ESTIMATOR FOR MOBILE RADIO COMMUNICATIONS"</p> <p>COMMUNICATIONS - GATEWAY TO GLOBALIZATION. PROCEEDINGS OF THE CONFERENCE ON COMMUNICATIONS, SEATTLE, JUNE 18 - 22, 1995,</p> <p>vol. 2, 18 June 1995 (1995-06-18), pages 998-1002, XP000533147</p> <p>INSTITUTE OF ELECTRICAL AND ELECTRONICS ENGINEERS ISBN: 0-7803-2487-0</p> <p>page 999, right-hand column, last paragraph - page 1000, right-hand column, last paragraph</p> <p>---</p>	2-10
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A	<p>YOW-JONG LIU ET AL: "A SOFT-OUTPUT BIDIRECTIONAL DECISION FEEDBACK EQUALIZATION TECHNIQUE FOR TDMA CELLULAR RADIO"</p> <p>IEEE JOURNAL ON SELECTED AREAS IN COMMUNICATIONS,</p> <p>vol. 11, no. 7,</p> <p>1 September 1993 (1993-09-01), pages 1034-1045, XP000400013</p> <p>ISSN: 0733-8716</p> <p>page 1036, left-hand column, paragraph 3 - right-hand column, paragraph 3; figures 3,4</p> <p>---</p> <p>-/--</p>	1

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